Chapter 15
Understanding Water-Energy-Food Nexus in Urban Ecosystem for Resilience to Climate Risks

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Abstract Growing population, urbanization, changing climate, increasing prosperity and change in dietary habit is putting unprecedented challenge on Water, Energy and Food (WEF) resources of India. WEF nexus has been gaining global momentum today and developing synergies between them for optimization of resource use is the demand of the hour. This paper is an attempt to analyze the importance of nexus approach for India and develop an interrelationship between Water, Energy and Food from consumption point of view for better management of natural resources through literature review and analysis of available secondary data. The finding comes up with few recommendations like integrated development of cities, concept of sustainable food consumption, integrated policy approach, green economy approach and ecosystem based approach for optimal use of resources. The connections between Water, Energy and Food is so robust that improving efficiency in one process either through technological interventions or through regulatory approach will have impact on the overall nexus elements and thus helps in achieving the goals of Sustainable Urban Development.

Keywords Water-energy-food nexus · Climate change · Urbanization · Sustainable development

15.1 Introduction

Ecosystems are dynamic complexes of living communities and their non-living environment interacting as functional unit. Ecosystems are basis of life and livelihoods and provide essential services for existence and socio-economic well being of people living in the surroundings. Urban ecosystem represents the built

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environments with high human density (MEA 2005) which is highly managed by humans to satisfy their needs and demands. Ecologically, they are complex systems that show distinctive ecological characters, patterns, processes, disturbances and subtle impacts (Mariana 2008). The relationship between ecosystems and cities are interlinked and is often a two-way process. Ecosystems provide a multitude of physical and environmental services to cities and their residents which also help in enhancing city's resilience. However, the cities, which are rapidly urbanising and experiencing unplanned development is leading to a threatening decline in ecosystems. This is impacting the resilience of several cities across the world.

The world is under sustained process of urbanization which has led to major socio-economic and environmental changes. 60 years back the world urban population was 29% (UNDESA 2006), today it is 50% and as per the projections made, by 2050 it will grow by 72% (UNDESA 2012). The numbers of megacities are increasing across the globe and more than half of the world's megacities i.e. 28 out of 36 are found in Asia-Pacific (UNDESA 2018), three of which are in India. The point of concern is that, most of this growing population will be absorbed into rapidly growing cities, notably in Asia's fast developing economies (Bentham 2011). These huge urban agglomerations exceed the carrying capacity (Mathur and Sharma 2016) of the region and require enormous amount of water, energy and food within a small area to support them.

Though the concept is in use for ages, water-energy-food (WEF) nexus is being promoted as a management tool to address the issue of resource scarcity (World Economic Forum 2009; Hoff 2011; Middleton and Allen 2014) and develop synergy with economic growth, socio-ecological linkages and path of resilience (Hellegers et al. 2008; Rasul 2014). Thus, this approach has been used by many experts, researchers and organizations like FAO, ICIMOD, UNEP, Global Water Partnership and many more in order to develop synergies between water-energy-food system and aims to provide a framework for optimal use of resources to manage trade-offs between them (Hellegers et al. 2008; Rasul 2014). The WEF concept has been gaining global momentum over last few years and has become centre point for Sustainable Development discussions (Biggs et al. 2015). The SDGs 2 and 12 talks about zero hunger and responsible consumption and production respectively, SDG 6 is related to clean water and sanitation whereas SDG 7 lays emphasis on affordable and clean energy. Apart from these goals that are directly addressing the water, energy and food resources, there are certain goals which are cross cutting across the nexus sector. SDG 11 have implications on urban ecosystem and emphasizes on making cities inclusive, safe, resilient and sustainable by implementing integrated policies and plans for resource use efficiency and adaptation to climate change. SDG 13 is related to climate action and SDG 15 talks about life on land that lays emphasis on integrating ecosystem based approach in local planning and developmental processes (UN 2016). The WEF relationship is continuously evolving with changing resource conditions, development priorities and technological advancements and thus provides an interface to explore synergies for most positive outputs. Thus, an integrated approach towards harmonizing WEF nexus can play a crucial role in

developing countries like India which can lead to smarter and more resilient development solutions.

15.2 Vulnerability and Impacts

The growing population and speed of urbanization in India puts unprecedented challenge on its environment and natural resources. Currently, 400 million people in India live in towns and cities; which accounts for 33% of its total population, and it is likely to increase in the coming years putting stress on its resources if not managed sustainably. The report by Planning Commission (now NITI Aayog) projects that within 20 to 25 years another 300 million people will migrate to various cities and towns (The Planning Commission 2012). Rise in population, rampant urbanization, growing prosperity and transition in lifestyle demands for more water and energy along with increase in the demand of food. Urban development, growing population density and the infrastructure development like housing societies, mall and markets, highways, office premises etc., all will have an obvious impact on the energy efficiency, water use and availability of food to support this growing population. As stated by Hoff (2011), urban living promotes more resource intensive lifestyles and concentrates consumption and waste production and thus escalating the scarcity of natural resources base.

History is the evidence that no nation can survive for long if natural resources of a state are exhausted or polluted. Meadows, Meadows et al. (1974) came up with an excellent work on "Limits to Growth" where it has been illustrated that natural resources depletion may jeopardized the economic growth of the nation (Meadows et al. 1974). However, the work further stated that global equilibrium could be designed to alter the negative growth trend and set up a harmony between economy and ecological stability that is sustainable for future as well. Thus, developing synergies and interrelationship between water, energy and food security for optimization of resource use efficiency to sustain is one of the solutions to the above statement and it is also the demand of time. The concept has gained a global momentum over the past few years. The nexus plays a crucial role in developing countries like India which can lead to smarter and more resilient development solutions.

Recognizing the importance and relevance of nexus approach in assuring sustainable economic growth of the country, India organized its first event, the "India Water Week" on this very theme of "Water, Energy and food Security: Call for solutions" in April 2012. The event recognized the importance of inter linkages among different sectors (water, energy, food and environment) as well as emphasized on strengthening the institutional framework for the same. Steps have already been taken in the direction; however, research is required to understand and strengthen the nexus. This paper is an attempt to analyze India's understanding of the nexus approach and develop an interrelationship between Water, Energy and

Food from the consumption point of view for better management of natural resources, using literature review and analysis of available secondary data.

15.2.1 Drivers to Integrate Water, Energy and Food: Key Challenges

Amongst many stresses and challenges being faced by our country today, key drivers are population growth, urbanization, increasing prosperity, change in the dietary habit, environmental pollution and climate change. It is important to understand the connections between these drivers and nexus elements.

15.2.1.1 Rising Population

India stands second in the world only after China in terms of population and supports 17.5% of total world's population with just 2% of geographical land (Ministry of Agriculture 2011). As per the recent projections made by United Nations, India is on the way to be the most populous country by 2022, surpassing China within seven years. Population pressure on land and water resources is very high to meet its food and developmental priorities. Comparing the data of last 50 years, India's population has grown and doubled from 541 million in 1971 to 1210 million in 2011. To support its large and growing population, India made significant progress in the field of food grains, doubling its production from 108 million tons in 1970's to 218 million tons in 2011 (Ministry of Agriculture 2011) and reached a stage of self-sufficiency to surplus agricultural produce (Swaminathan and Bhavni 2013; Ahmad and Haseen 2012). The "Green Revolution" that started in late sixties and made India from a country of food grain importer to food grain exporter is to be credited for such progress.

However, to reach this stage of food sufficiency water resources were exploited manifold and have reached a stage of water stressed condition today. With only four percent of total global water available, agriculture remains the biggest use, accounting for almost 80% of water withdrawal. The demand for water will continue to rise in future due to rapid population increase and economic growth.

According to Rao (2002) and projections made by National Commission for Integrated Water Resources Development Plan (NCIWRDP), the requirement of water for irrigation in India will grow by more than 50% by 2050. The per capita water availability has declined from 5200 m^3 in 1951 to 1588 m^3 in 2010, showing a decrease of 69% which is more than double. As per the projections made it will decrease further to 1191m^3 by 2050 (http://india-wris.nrsc.gov.) almost reaching a stage of water scarce condition (Fig. 15.1).

Water is used in the production of almost all kind of energy and demand of electrical energy for agricultural usage is showing an increasing trend in India

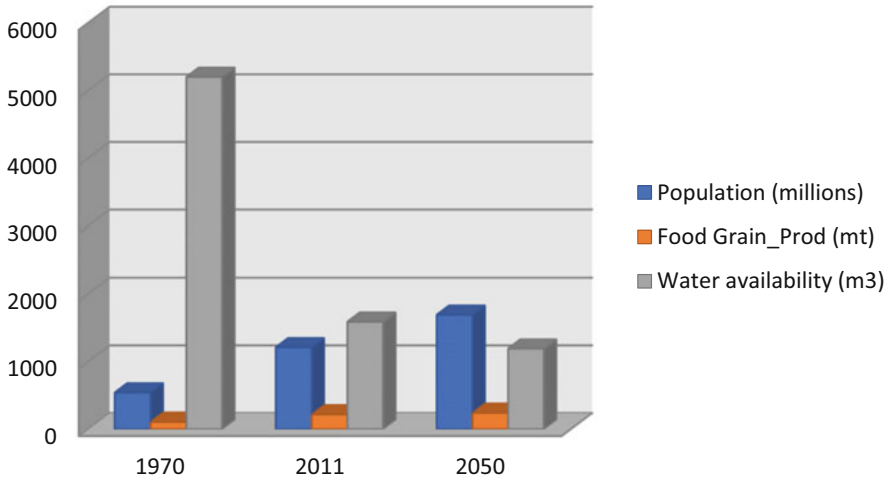

Fig. 15.1 Graph projecting the declining trend of water resources with increasing population & food production

(Swarnkar and Singh 2013). Mechanization of various agricultural operations in the supply chain including farm irrigation, harvesting, processing etc. accounts for the energy demand in agricultural sector. The energy consumption in terms of electric utility in our country has increased manifold during the last five decades. It has increased from 56 billion kwh in 1971 to 768 billion kwh today; which is 13 times more. According to United Nations, 90% of global electricity requires water either to rotate turbines or as a coolant in thermal power plants (Lundy and Bowdish 2013). Population will continue to rise and as per the projections made by various organizations (Planning Commission of India) by 2050, India's population will be 1690 million which implies that we need to increase the rate of production with limited land and available water resources. Thus water, energy and food needs are expected to increase in near future, in order to meet the demand of the growing population.

15.2.1.2 Urbanization

As urbanization continues, half of the world's population is living in cities, largely seeking increased economic opportunity to sustain them. An analysis of Indian Census data of last 50 years shows that number of urban agglomeration of towns and cities has grown more than three times from 1970 to 2011. Population residing in these urban areas has almost doubled and is likely to increase in coming years. If the current trend continues, it has been projected by United Nations that India's urban population will increase to 50% by 2050; showing an increase of almost 20% from current years (Fig. 15.2); intensifying the stress on its resources if not managed sustainably.

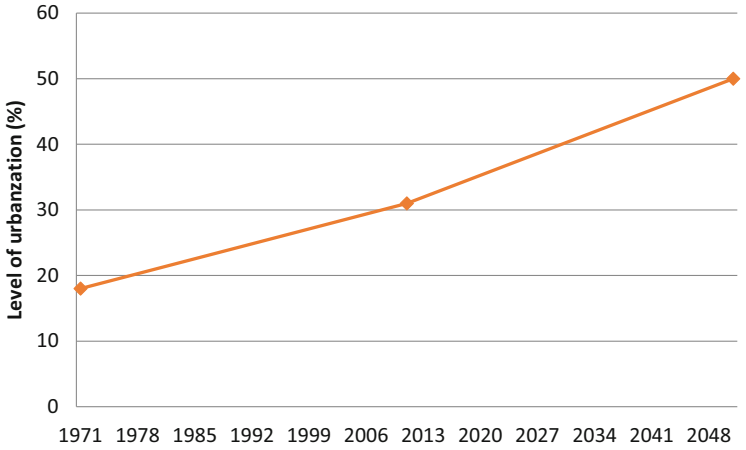

Fig. 15.2 Line chart projecting level of urbanization in India

As stated by Dutta (2006), India's urbanization has been termed as "over-urbanization" or "pseudo-urbanization" because of inordinately large population size in big cities leading to virtual collapse in the urban services followed by basic problems in the field of housing, sanitation, slums, water, infrastructure as well as quality of life. The current pattern of urbanization is actually taking place on the fringes of cities, wherein, putting pressures on Municipal Corporations for the supply of basic amenities. In urban water supply and municipality, sanitation, wastewater treatment and drinking water supply, energy is required at every step and forms the main operational cost component. In most cities, water supply is sourced from long distances and the length of pipeline determines the cost including the cost of pumping water. The very process of collecting, transporting and distributing water is energy intensive and cost of operation is very high. As per the Planning Commission of India (now NITI Aayog), 75% of urban households are covered with piped water; 40–50% of water is lost in the distribution system and approximate 30–50% electricity is spent to pump water in most Indian cities (Planning Commission 2011). This rapid and accelerating economic growth, growing population, burgeoning middle class, expanding cities and urbanization are increasing the demand for water, energy and food.

15.2.1.3 Increasing Prosperity and Change in Dietary Habit

India's per capita income has grown ten times in the past six decades. As per the report of Rangrajan Committee on poverty status in India (Planning Commission 2014) there has been a significant decline in the Indian poverty ratio-which fell down from 38.2% to 29.5%, lifting almost 10% of population out of poverty line. This implies that more and more people have migrated to cities and burgeoning middle class and thus the purchasing power of individual has increased substantially. This is

Table 15.1 Water and energy input for processes foods (Source: *IME (2013), **Pimental (2011))

S. No	Food stuff	Water consumed (litres)*	Energy consumed (Kcal/kg)**
1	Chocolate (Kg)	17,196	18,948
2	Meat (kg)	10,412	1206
3	Milk (l)	1022	354
4	Wine (l)	436	830
5	Coke (l)	600	1425

indeed a positive development but it will be accompanied by increase in the demand and supply of basic amenities, intensifying the environmental stresses and putting pressures on natural resources.

Food basket has diversified significantly with the rising incomes of the country. The economic growth, urbanization and taste preferences have resulted shift in food consumption pattern deviating from traditional food commodities (Meenakshi 1996; Murty 2000; Amarsinghe et al. 2007; Pathak et al. 2010). Indian diet is diversifying with fruits/vegetables and animal based food share increasing and cereal and pulses declining (NCEAR 2014). Increase in income has also changed the dietary habit of affluent urban people where consumption of processed foods and ready to eat foods has gone up (Vepa 2004). There has also been an increase in the nutritional intake in terms of calories and it is projected to increase to 3000 calories in 2050 from 2495 calories at present.

According to the NSSO report of 2013, there is around 33% increase in the consumption expenditure from 66th round to 68th round (Sinha 2014) where expenditure on beverages, refreshment and processed food is highest and forms the significant amount to drive the food sustainability issues. Energy is used in the production, processing as well as delivery of food, pumping of water for irrigation, transport of food, its distribution and storage. The full food production and supply chain is responsible for around 30% of total global energy demand (Hoff 2011). Food processing consumes substantial amount of energy, which is comparatively high in bread, animal food products and sugar processing (UNIDO 1995). The Table 15.1 gives water and energy inputs for some of the processed foods most commonly used these days.

Government policies are predominantly focused on the production side to increase the food availability in order to feed billion populations. But at present, around one-third of all food produced is lost along the food supply chain and considerable amount of food gets wasted at consumption level. It has been estimated by FAO (2011) that global food loss and waste is approximately 1.3 billion tons annually and occurs at point throughout the supply chain and across the socio-economic spectrum (Moomaw et al. 2012). In India, the domestic food loss has been estimated to be 30–40% of total food supply (Emerson Report 2013). A significant share of total energy and water inputs are embedded in these losses. Therefore, there is an urgent need to develop holistic and effective strategies for promoting sustainable consumption as well as improving the food supply chain vis-a-vis efficient production, which will address the nexus issues.

15.3 Case Study of Gurugram: A Study at Micro Level

Gurugram is one of the largest cities of Haryana, which is urbanizing and expanding at a very fast rate. With the advent of economic reforms and modernization in 1990s, the cultural and ecological landscape of the city has undergone a rapid change. Apart from real estate development, the city has emerged as one of the prominent business hub in North India because of the favourable tax policy of the Haryana State Government, rapid development of infrastructure as well as good connectivity with the International Airport. Many automobile and software multinationals have found their way into the city premises due to the availability of high level of infrastructure of airways, railways, highways, medical and educational institutions in its close proximity.

Despite its planned and gleaming infrastructure, the government has not been able to keep at pace with the growing population and increasing level of urbanization in the city. The areas that are dilapidated and poorly connected, lacks adequate water and power supply with no proper sewage handling mechanisms. The city regularly faces water scarcity and water quality problems are acute during summer season. The city meets its water supply demand from Yamuna Nagar Canal and groundwater. Groundwater is used to supplement the water need that constitutes the main source of water for construction sector. The unsustainable developmental pattern has led to some obvious consequences with wells running dry and city turning into a concrete desert.

The population of the city (as per 2011 census) is 1.5 million, where male and female constitutes 54% and 46% of the population respectively (GoI 2011). The total water demand of the city as per the city agencies is 184 MLD. Water required for cooking is approximately 11 MLD, which is 6% of the total water demand. This water requirement includes water for cooking as well as washing utensils. The city needs more than 1 lakh kg of energy in form of LPG for cooking raw food whereas, 854.64 Mwh of electricity in consumption of food other than cooking. This includes reheating, processing and storage of foods using electrical appliances. In addition the city needs 114.6 Mwh of energy in the form of electricity for pumping water into the storage tanks which is further used for cooking along with other purposes like washing clothes, sanitation and domestic use.

In the past two decades, Gurugram city has experienced urban growth at a phenomenal rate. The rapid rate of population growth and increasing urbanization resulted in fast deterioration in the quality of life for the mass living in the city. Prosperity and growth of a region depends upon the availability of infrastructure and services. Water and energy is the most crucial among these. Advance planning for development of such resources are necessary, taking into account the projected population of the region. Hence, in such scenarios the water energy food nexus provides a synergy and must be looked upon for optimization of resources to meet the future demands.

15.4 Mitigation and Management

The key mitigation and management strategies for optimizing the WEF nexus are:

15.4.1 From Master Plan to Integrated Development of Cities

India is growing very fast in terms of population as per the recent projections made by United Nations. Therefore, proper planning should be done by taking the cognizance of projections made for the future; otherwise the country will face unprecedented level of urbanization and unmanageable concentration of population. Master plans of the country have been unable to cope up with the pace of growth of Indian cities. Inefficient regional planning approach has led to proliferation of slums in cities. As per the 12th Five Year Plan of India very few Indian cities have 2030 master plans that take into account basic services like water, sanitation, food, transportation, roads etc. It is time to develop an integrated development of "smart cities" which aims at developing the urban ecosystem by strengthening institutional, physical, social and economic infrastructure. Ministry of Housing and Urban Affairs (MoHUA) has already taken a step by releasing a new Urban and Regional Development Plan Formulation and Implementation Guidelines (URDPFI) in 2015. The plan came with the objective of replacing the existing 1996 guidelines of formulating master plans in all cities of the country. Thus cities and towns need to be designed to be compact and connected, with energy efficient transport, green buildings, easy and secure access to water and food.

15.4.2 Sustainable Food Consumption

The food consumption pattern of India's urban and burgeoning middle class is changing with change in lifestyle and increasing prosperity. Research shows that there is increasing trend towards fast food and ready to eat food with more shares of animal products, sugar and fats. The change in food habit is not only causing health related issues like obesity and hypertension but significant amount of water and energy gets wasted at consumption level. According to FAO and UNEP, Sustainable Food System Program, which was adopted at the Rio+20 Conference in 2012, consumers exert strong influences through the ways they buy, transport, conserve, cook and consume their food. Food availability, food accessibility, food choice, geography, demography, socio-economic status, urbanization, culture, marketing and consumer attitudes etc. should be considered while developing holistic and effective strategies for promoting sustainable consumption as well as improving the food supply chain vis-a-vis efficient production which will address the nexus issues.

15.4.3 Governance, Institutions and Integrated Policy Approach

Urban planning and management in India is a state subject. With the enactment of the 74th Amendment Act of India in 1992, Urban Local Bodies (ULBs) like Municipal Corporations and Municipal Councils were constituted and entrusted with the task of town planning as well as social and economic development of the urban areas. Cities are growing beyond the municipal boundaries, hence, ULBs needs to be strengthened for the proper management of cities. Proper institutional mechanisms need to be relooked so that ULBs have their defined roles and responsibilities. Currently, India does not have policies that look at food, water and energy sectors in an integrated manner. Policies in the energy, water and food can only be successful if they are interlinked with each other, inclusive of climate change and environment policies.

15.4.4 Green Economy Approach

"Green economy" and "Green Growth concept" are new policy approaches promoted in many international conferences and seminars to address the WEF nexus. The green economy promotes low carbon, efficient utilization of resources and social inclusion as drivers for sustainable development. Investing more on renewable energy, increasing efficiency in irrigation system, sustainable agriculture, reducing food wastage, checking water wastage, increasing fuel efficiency, etc. will reduce the carbon footprint along with addressing the nexus issues. India has already taken steps towards developing a road map for transition towards green economies; however, more investment is needed on research and development focusing on green solutions.

15.4.5 Ecosystem Approach

Ecosystem-of which we are an integral part-provides us with many goods and services (regulating, provisioning, supporting and cultural services) that are required to sustain our livelihood. Organizations like International Centre for Integrated Mountain Development (ICIMOD) and United Nations Environment Program (UNEP) have promoted ecosystem based approaches in addressing WEF nexus policy dialogues. The ecosystems must be protected and enhanced to ensure the resilience of water, energy and food sectors.

15.5 Conclusion and Way Forward

This study reveals that increase in population, urbanization and economic growth will strain the demand-supply balance of water, energy and food resources and estimates show that by 2031 the average supply of water and energy per person will drop significantly putting stress on the natural resource base of the country.

According to Fifth Assessment Report of IPCC, climate change and anthropogenic greenhouse gas emissions are the functions of increasing population size, unsustainable economic activity, prosperity and change in lifestyle, intensive energy use, land use patterns, technology and climate policy of a nation (IPCC 2014). Thus, it is imperative to develop future adaptation strategies in order to reduce the risks and vulnerability of climate change impacts and contribute to the Goals of Sustainable Development for the well-being of human beings. Developing adaptation framework is very context specific (IPCC 2014; IPCC 2007) and needs to be integrated into development plans, policy and decision making to promote synergies across the sectors. This framework can be very well aligned with India's National Mission on water, solar energy, enhanced energy efficiency and sustainable habitat.

Energy and water is required at all stages of food production as well as consumption. The interrelationship is so sturdy and strong, that improving the efficiency in one process will have impact on the overall nexus elements. These interventions will also help to achieve the targets envisaged in Sustainable Development Goals by 2030 along with achieving the targets of National Action Plan on Climate Cshange. India needs to work on several areas to manage its developmental goal along with key challenges like urbanization and rising population.

Henceforth, the nexus approach identifies synergies between social, institutional, environmental and economic pillars of the society and mainstream the concept of "sustainable development" in planning at global, regional and national level.

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